EXPERIENTAL STUDY ON PARTIAL REPLACEMENT OF GLASS USING CELLULAR LIGHT WEIGHT CONCRETE

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ABSTRACT

Cellular Lightweight Concrete (CLC) is an emerging material in the construction industry known for its low density, excellent thermal insulation, and eco-friendly composition. Created by incorporating stable foam into a cementitious slurry, CLC offers a sustainable alternative to traditional concrete, utilizing materials such as fly ash to enhance its environmental performance. The resulting concrete is lightweight yet sufficiently strong for a variety of applications, including partition walls, non-load-bearing structures, and thermal insulation layers. This paper presents an overview of the production techniques, material characteristics, and potential uses of CLC, emphasizing its advantages in reducing dead load, construction time, and overall building costs. With its unique combination of performance and sustainability, CLC represents a significant advancement in modern construction practices.

Mixes with varying percentages Cellular Lightweight Concrete (CLC) is gaining popularity as a sustainable and efficient building material due to its low density, thermal insulation, and ease of handling. This research explores the impact of partially replacing cement in CLC with alternative materials such as fly ash, ground granulated blast furnace slag (GGBS), and silica fume. These industrial by-products not only help in reducing cement consumption but also contribute to lowering carbon emissions and improving concrete properties. The study involves preparing CLC of replacement materials and analyzing their effects on density, compressive strength, and workability. The results demonstrate that certain replacement levels enhance the performance of CLC while also making it more environmentally friendly. The findings highlight the potential of using waste materials to develop cost-effective and sustainable lightweight concrete suitable for modern construction needs.

1.INTRODUCTION

In the modern construction industry, the demand for innovative, sustainable, and cost-effective building materials has led to the development and widespread use of **Cellular Lightweight Concrete (CLC)**. CLC is a type of lightweight concrete that incorporates stable air bubbles into a cementitious mix using a foaming agent. This results in a significantly lower density compared to conventional concrete, while still offering adequate strength for various structural and non-structural applications.

The absence of coarse aggregates and the inclusion of foam make CLC not only lighter but also easier to handle and transport. It offers additional advantages such as excellent thermal insulation, sound absorption, fire resistance, and reduced construction costs. These characteristics make CLC particularly suitable for applications like partition walls, roof insulation, and pre-cast blocks.

With growing emphasis on sustainability, there is increasing interest in partially replacing cement or other constituents of CLC with industrial by-products such as **fly ash, silica fume, or ground granulated blast furnace slag (GGBS)**. These materials help lower the environmental impact of concrete production while enhancing its performance in terms of durability and workability.

Thus, Cellular Lightweight Concrete represents a forward-thinking solution that combines environmental responsibility with practical construction benefits.

LITERATURE REVIEW 1

- S.Bhandari and Dr.K.M.Tajne: In this research paper they have concluded that the compressive strength for cellular light weight concrete is low for lower density mixture.
- The performance of cellular lightweight concrete in term of density and compressive strength are investigated.

LITERATURE REVIEW 2

- HjhKamsiahMohd.Ismail, Mohamad Shazli Fathi and NorpadzlihatunbteManaf:
- In this study paper the main specialties of lightweight concrete are its low density and thermal conductivity.
- Its advantages, disadvantages and applications were studied thoroughly.

LITERATURE REVIEW 3

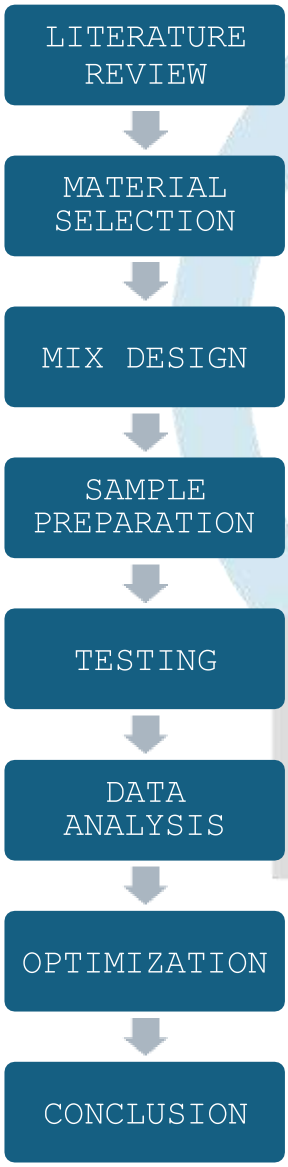
- Satyendra Kumar Meena, Pushpendra Kumar Meena, Rakesh Kumar Meena, Rupayan Roy and Pawan Kumar Meena:
- It was studied that cellular lightweight concrete possesses high flow ability, low self-weight, minimal consumption of aggregate, controlled low strength and excellent thermal insulation properties.

- It has excellent resistance to water and frost, and provides a high level of both sound and thermal insulation.

LITERATURE REVIEW 4

- KrishnaBhavaniSiram: This paper shows that how the cellular concrete can be used as a replacement of burnt clay bricks.
- An attempt is made to compare cellular lightweight concrete (CLC) Blocks and Clay Bricks, and recommend a replacement material to red brick in construction industry.

METHODOLOGY



4.MATERIAL USED

1. Cement

- **Type:** Ordinary Portland Cement (OPC) – commonly 43 or 53 grade
- **Function:** Main binding material for the concrete matrix
- **Alternatives:** Portland Pozzolana Cement (PPC), Blended Cements

2. Fine Aggregate (Optional or Minimal)

- **Material:** River sand, crushed sand, or manufactured sand (M- sand)
- **Function:** Improves the density and strength when used
- **Note:** In some CLC mixes, fine aggregate may be omitted to produce ultra-lightweight concrete

3. Water

- **Function:** Needed for hydration of cement and to mix all ingredients
- **Quality:** Clean and potable; free from impurities (organic/inorganic)

4. Foaming Agent

- **Type:** Protein-based (natural) or synthetic surfactant-based
- **Function:** Creates stable air bubbles that make the concrete lightweight
- **Application:** Foam is generated separately and then mixed with slurry

5. Fly Ash (Optional, but Commonly Used)

- **Type:** Class F (low-calcium) fly ash
- **Function:** Partial replacement for cement; improves workability and reduces cost
- **Benefits:** Enhances durability and minimizes shrinkage

6. Additives / Admixtures (Optional)

- **Types:**
  - **Superplasticizers:** Improve flow without increasing water
  - **Accelerators/Retarders:** Modify setting time based on conditions
- **Function:** Tailor workability, strength development, or curing time

7. Lightweight Aggregates (For Certain Mixes)

- In some formulations (especially semi-cellular or structural CLC), lightweight aggregates may be added:

- **Expanded perlite**
- **Expanded clay**
- **Pumice**
- **Cenospheres** (from fly ash)

- **Function:** Further reduce density or improve insulation

MIX DESIGN

- **Target Wet Density: 1600 kg/m³**
- **Compressive Strength (28 days): ~7–10 MPa**
- **Glass Replacement Level: 20% of fine aggregate by weight**
- **Glass Form: Crushed waste glass (size < 4.75 mm)**

Material	**Quantity (Approx.)**	**Notes**
Cement (OPC 43/53)	**350 kg**	**Binder**
Material	**Quantity (Approx.)**	**Notes**
Fine Aggregate (Sand)	**480 kg**	**80% of total aggregate**
Crushed Glass	**120 kg**	**20% replacing sand**
Water	**180 liters**	**Water-to-cement ratio ~0.5**
Foaming Agent	**As per manufacturer spec**	**To create approx. 400–500 L of foam**
Fly Ash (optional)	**Up to 100 kg (if used)**	**Can replace part of cement to improve workability and reduce cost**

Step-by-Step Mixing Process

1. **Dry Mixing: Combine cement, fine aggregate, and crushed glass in a mixer until uniformly blended.**
2. **Add Water: Gradually add water to form a consistent slurry.**
3. **Foam Generation: Use a foam generator to produce stable pre- formed foam using the foaming agent.**
4. **Foam Addition: Gently fold foam into the slurry while mixing until the desired wet density (1600 kg/m³) is achieved.**
5. **Casting: Pour the mix into molds or formwork.**
6. **Curing: Cover with plastic or keep moist for at least 7 days to ensure proper hydration.**

Advantages of Using Crushed Glass:

Feature	Benefit
Recycled content	Eco-friendly and sustainable
Good workability	Enhances mix texture
Glass as filler	Reduces natural sand usage
Improved finish	Smoother surfaces on blocks

Precautions:

- **ASR (Alkali-Silica Reaction): To reduce risk, use pozzolanic materials like fly ash or silica fume.**
- **Trial Mix: Adjust foam and water content based on field conditions.**
- **Limit Replacement: Keep glass replacement below 25% for best durability and safety.**

TESTING

1. Density Test (Wet & Dry Density)

- **Purpose:** To determine if the mix meets the target lightweight density.
- **Standard:** IS 2185 (for concrete blocks) or ASTM C138 (for concrete density)

- **Procedure:**
  - Fill a known volume mold with fresh concrete.
  - Weigh it to determine wet density.
  - After curing, weigh the dry specimen for dry density.

2. Compressive Strength Test

- **Purpose:** To evaluate load-bearing capacity.
- **Standard:** IS 516 / ASTM C39
- **Specimen Size:** 150 mm cubes (or 100 mm for small-scale work)
- **Test Ages:** Typically tested at 7, 14, and 28 days.

3. Water Absorption Test

- **Purpose:** To assess porosity and durability.
- **Standard:** IS 2185 Part 1 (for concrete blocks)
- **Procedure:**
  - Weigh dry sample → Soak in water for 24 hours → Weigh again
  - Water absorption = (Wet weight - Dry weight) / Dry weight × 100%

4. Workability Test (Slump Test)

- **Purpose:** To check the ease of mixing and placing the concrete.
- **Standard:** IS 1199 / ASTM C143
- **Note:** Not always reliable for foam concrete; **flow table test** may be used instead.

5. Air Void Analysis / Foam Stability Test

- **Purpose:** To ensure uniform distribution and stability of air bubbles.
- **Method:** Check for segregation and collapse in fresh concrete visually and using lab methods.

6. Durability-Related Tests (Optional for Long-Term Studies)

Test	Purpose	Standard
Alkali-Silica Reaction (ASR) Test	To assess risk of expansion/cracking due to glass	ASTM C1260 (Accelerated Mortar Bar Test)
Chloride Penetration Test	To assess resistance to chemical attack	ASTM C1202
Thermal Conductivity Test	For insulation evaluation	ASTM C518

7. Microstructure Analysis (Optional, Research Level)

- **SEM (Scanning Electron Microscope):** To observe bonding between glass particles and cement matrix.
- **XRD / FTIR:** For phase analysis of glass-cement interactions.

DATA ANALYSIS

1. Objective of Analysis

To determine the effects of partially replacing fine aggregates with **waste glass powder** in CLC in terms of:

- **Compressive strength**
- **Density**
- **Water absorption**
- **Thermal conductivity**
- **Workability**

2. Experimental Design

a. Mix Proportions

Prepare multiple mixes with varying glass powder replacement levels:

MIX ID	GLASS POWDER (%)	CEMENT (kg/m^3)	FLYASH (kg/m^3)	FINE AGGREGATE (kg/ m^3)
M0	0%	300	150	500
M1	10%	300	150	450+50 glass
M2	20%	300	150	400+100 glass
M3	30%	300	150	350+150 glass

3. Test Results

a. Compressive Strength (Mpa)

MIX ID	7 Days	14 Days	28Days
MO	2.6	3.6	4.1
M1	2.9	4.0	4. 5
M2	3.2	4.3	5.0
M3	2.7	3.7	4.2

b. Density

- Dry density is measured after curing Wet density is measured immediately after mixing.
- (typically 28 days).
- Density decreases with increasing glass powder due to the lower specific gravity of glass and reduced cement content.
- These values are indicative. Exact results vary based on foam content, water-cement ratio, and curing conditions.

c. Thermal conductivity

Thermal Conductivity and Density:

Research indicates a predictable polynomial relationship between thermal conductivity and density in ceramsite cellular concrete. This means that as density increases, thermal conductivity also tends to increase.

Ceramsite Volume Proportion:

For CLC with a design density of 600 kg/m³, a ceramsite volume proportion of 45% has been found to optimize thermal conductivity and compressive strength.

Glass Replacement Benefits:

Partial replacement of cement with glass powder has been shown to improve mechanical properties, which can contribute to better thermal performance.

Comparison with Conventional Concrete:

Studies have observed clear improvements in thermal conductivity and insulation criteria in lightweight concrete mixtures compared to conventional ones [1] [2] [3].

D.Workability

Glass Powder Addition:

Studies indicate that adding glass powder as a cement replacement can impact workability. However, specific effects depend on the proportion of glass powder used and the design mix.

Waste Glass Replacement:

Replacing fine aggregates with waste glass can maintain workability up to a certain percentage. Research shows that replacing 40% of fine aggregate with waste glass didn't significantly change concrete strength [1].

Target Parameters:

- Target Wet Density: 1600 kg/m³
- Water-Cement Ratio (w/c): 0.5
- Glass Powder Replacement: 20% by weight of cement
- Foam Volume: Adjusted to achieve target density
- Cement Density: 3150 kg/m³
- Glass Powder Density: 2500 kg/m³
- Sand: Optional (often omitted in low-density CLC)

Mix Design (per m³ of CLC)

Step 1: Assume Cementitious Material Content

Total cementitious binder = 400 kg/m³ (includes cement + glass powder)

Step 2: Glass Powder Replacement

Glass powder = 20% of 400 = 80 kg

Cement = 400 - 80 = 320 kg

Step 3: Water Content

Water = w/c × Cement = 0.5 × 320 = 160 kg

Step 4: Foam Content

Dry unit weight of solids (cement + glass) = (320 × 3.15 + 80 × 2.5) / 1000 = ~1.22 tons

Approx. volume of solids + water = (320/3150 + 80/2500 + 160/1000) ≈ 0.268 + 0.032 + 0.16 = ~0.46 m^3

Foam volume needed = 1 - 0.46 = 0.54 m^3

Foam is generated by mixing foaming agent with water and air using a foam generator.

Final Mix Proportions (per m^3):

Material	Quantity (kg)
Cement	320
Glass Powder	80
Water	160
Foam (volume)	~0.54 m^3

Conclusion

The experimental study on the partial replacement of glass in Cellular Lightweight Concrete (CLC) demonstrates that waste glass can be effectively utilized as a sustainable alternative material in concrete production. The inclusion of finely ground waste glass, when used in suitable proportions (typically 10–20%), enhanced certain properties of CLC such as compressive strength, thermal insulation, and durability, while maintaining its lightweight characteristics.

It was observed that up to an optimal percentage of replacement, the pozzolanic activity of glass particles contributed positively to the strength development due to the reaction with calcium hydroxide. However, beyond this optimal point, a decline in strength was noted, likely due to alkali-silica reaction (ASR) risks or improper bonding.

This study confirms that partial replacement of glass in CLC is not only feasible but also beneficial from both environmental and economic perspectives. It supports the recycling of waste glass and promotes the use of green construction materials. Further long-term studies are recommended to assess durability and ASR mitigation strategies for higher glass content.

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